A UNIFIED LUNAR CONTROL NETWORK

Merton E. Davies and Tim R. Colvin, The RAND Corporation, Santa Monica, CA 90406
Donald L. Meyer, Defense Mapping Agency, Aerospace Center, St. Louis AFS, MO 63118

At this time, control on the Moon is composed of a number of independent regional networks. These networks frequently have different origins but never have common ties, even in overlapping areas. The objective of the unified network program is to tie the regional networks into a single consistent planetwide control network. The plan is to start with the best defined regions, create common ties with neighboring data sets, and then expand into poorly defined regions.

The most accurately defined points on the Moon are locations of the laser ranging retroreflectors (Ferrari et al., 1980) and the VLBI measurements of the locations of the Apollo 15, 16, and 17 ALSEP stations (King et al., 1976). Recent values for the coordinates of the retroreflectors have been received from Williams and Dickey, 1986. The accuracy of these locations is about 30 m and their locations are used to define the center-of-mass and, hence, the origin of the unified lunar coordinate system. The coordinates of the retroreflectors are given in both principal axis and mean Earth/Polar axis systems. Mean Earth/Polar axis coordinates have been recommended by the IAU (Davies et al., 1980) for the moon. The difference in the coordinates is important, more than 600 m in latitude and longitude.

The Apollo 15, 16 and 17 ALSEP stations have been identified on Apollo panoramic photography and their locations transferred to Apollo mapping frames. Thus, their coordinates are available in the control network computations.

Three control networks have been computed based on the Apollo mapping pictures. They are the DMA/A15 system (Schimerman, 1976), the NOS/USGS system (Doyle et al., 1977), and the DMA/603 system (DMAC Contract Report, 1981). The DMA/A15 system contained 1284 pictures and 9940 points, the NOS/USGS system contained 1244 pictures and 5324 points, and the DMA/603 system contained 603 pictures and 5346 points. The coordinates of points in one system can be transferred to another system by interpolation between nearby common points. Thus the coordinates of the three ALSEP stations which are available in DMA/A15 coordinates, are transferred to NOS/USGS and DMA/603 coordinates. The coordinates are based on picture measurements and the photogrammetic solutions and can then be compared to the coordinates derived by King et al., 1976 and Ferrari et al., 1980.

In order for the control network to have the same origin and mean Earth/Polar axis coordinate system defined by Ferrari et al., 1980, the coordinates of the ALSEP stations should be identical. The RMS of the true distance between corresponding ALSEP points is 333 m for the DMA/A15, 2110 m for NOS/USGS, and 308 m for DMA/603. Transformations permitting translation, rotation, and scale (7 parameters) have been computed for each control system to minimize the distances between these corresponding points. The RMS of the residuals after the transformations is 73 m for DMA/A15, 76 m for NOS/USGS, and 58 m for DMA/603. After the transformation, the coordinates of points in all three systems are quite similar. The DMA/603 transformed system was selected as the preferred system and called DMA/603 MOD.

Many control networks have been computed based on pictures of the Moon taken through telescopes; these cover the Earth-facing region. Probably the most carefully prepared network is that published by Meyer, 1980. This is the one incorporated into the present program. 130 points common to Meyer's and the Apollo networks were selected and transformation parameters computed to shift Meyer's coordinates to the DMA/603 MOD network. The RMS of the residuals of this transformation is 808 m. The mean shift of the coordinates was 1352 m, with a maximum of 2336 m and a minimum of 803 m. All 1088 points from Meyer's network were transformed to the DMA/603 MOD system. The mean shift of the coordinates of all of the points was 1390 m with a maximum of 2603 m and a minimum of 493 m.

References

Davies, M. E. et al., "Report of the IAU Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites," Celestial Mechanics, Vol. 22, January 1980, pp. 205-230.

Doyle, Frederick J., Atef A. Elassal, and James R. Lucas, "Selenocentric Geodetic Reference System," National Oceanic and Atmospheric Administration, Technical Report NOS70NGS5, February 1977.

Ferrari, A. J., W. S. Sinclair, W. L. Sjogren, J. G. Williams, and C. F. Yoder, "Geophysical Parameters of the Earth-Moon System," J. Geophys. Res., Vol. 85, No. B7, July 10, 1980, pp. 3939-3951.

King, R. W., C. C. Counselman III, I. I. Shapiro, "Lunar Dynamics and Selenodesy: Results from Analysis of VLBI and Laser Data," J. Geophys. Res., Vol. 81, No. 35, December 10, 1976, pp. 6251-6256.

Meyer, Donald L., Selenocentric Control System (1979), Defense Mapping Agency, DMA TR 80-001, April 1980.

Report on Lunar Control under Contract No. W-14, 453, Defense Mapping Agency Aerospace Center, St. Louis AFS, MO 63118, October 1981.

Schimerman, Lawrence A., The Expanding Apollo Control System, Defense Mapping Agency Aerospace Center, August 1976.

Williams, J. G. and J. O. Dickey, Coordinates of the Lunar Laser Retroreflectors, Letter to M. E. Davies, June 18, 1986.